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1. Your reference	JKH/BA/UNIBR.15	
2. Patent application number *(The Patent Office will fill in this part)*	25 SEP 1997	**9720443.2**
3. Full name, address and postcode of the or of each applicant *(underline all surnames)*	UNIVERSITY OF BRISTOL Senate House Tyndall Avenue Bristol BS8 1TH	
Patents ADP number *(if you know it)*		7981800 1
If the applicant is a corporate body, give the country/state of its incorporation	UNITED KINGDOM	
4. Title of the invention	DENTAL CURING	
5. Name of your agent *(if you have one)*	JEFFERY KEITH HOGG	
"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	WITHERS & ROGERS 4 Dyer's Buildings Holborn London EC1N 2JT	
Patents ADP number *(if you know it)*	1776001	

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number	Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
a) any applicant named in part 3 is not an inventor, or
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Continuation sheets of this form	
Description	5
Claim(s)	2
Abstract	1
Drawing(s)	2 + 2

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Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	1
Request for substantive examination *(Patents Form 10/77)*	
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11. I/We request the grant of a patent on the basis of this application.

Signature
for Withers & Rogers (Agents)

Date
24.09.97.

12. Name and daytime telephone number of person to contact in the United Kingdom

JEFF HOGG 0117 9253030

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DENTAL CURING

This invention relates to an optical irradiation device, especially a compact portable irradiation device suitable for use as a light polymerisation source.

It has already been proposed to use light-emitting diodes LEDs in a hand held device to produce a focused beam of light to cure dental materials. Blue light at a peak wavelength of about 470nm is used to harden dental polymers which contain camphoroquinone as the photoinitator in a methacrylate polymerisation process. However, there is a problem in producing a sufficient level of irradiance even with a clustered array of LEDs, to cure the known dental polymers in the recommended time. At the lower levels of irradiance available generally below 300mW/sq.cm, longer curing times have to be allowed, which reduces the efficiency of the dental treatment delivered.

An object of the present invention is to provide an optical irradiation device that employs LEDs, and thereby has the benefits of compactness, portability, ruggedness and long life, but which also produces improved levels of irradiance at and above 300mW/sq.cm.

According to the invention, LEDs are clustered in an irradiation device by forming shaped faces on adjacent LEDs which allow them to abut more closely face-to-face than they would otherwise with conventional spherical outer surfaces as manufactured currently.

Thus the LEDs occupy more of the available space, and a fixed number produce a higher radiant intensity. Thus, smaller numbers of LEDs can be used to produce a desired level of irradiance, which in turn reduces the power required to drive the device and the heat generated by it. Furthermore, the device can be made more compact.

Typically, a central LED might have a polygonal outer surface, and a first ring of LEDs would be arranged around it, each with a flat face to abut a corresponding face of the central LED and possibly each having a pair of radiating side faces which abut adjacent LEDs in the first ring. Furthermore, a second or more rings of LEDs could be arranged concentrically with the first ring, each with respective adjacent flat side faces abutting one another and possibly with inwardly diverted faces abutting respective outwardly directed faces of the LEDs of the first ring.

In one embodiment of the invention shown in Figure 1 hexagonal LEDs 11, may be clustered in the manner of a honeycomb. In a second embodiment of the invention shown in Figure 2, a central hexagonal LED 21 may abut flat faces of six LEDs 22 in a first ring contained within a second ring of LEDs 23 with radiating side faces that allow adjacent LEDs in the second ring to abut one another. In a third embodiment of the invention shown in Figure 3, an inner ring of nine LEDs 31 in a first ring is contained within a second ring of LEDs 32 with radiating side faces that allow adjacent LEDs in the second ring to abut one another. In both the second and third embodiments, the adjacent faces of the LEDs of the first and second ring may also be shaped to abut one another. It will be appreciated in all three embodiments, the LEDs are mounted in a substantially flat plane.

In modifying the conventional characteristics of the optical sphere shape of a LED, the outer plastics envelope that encapsulates the light-emitting semiconductor Pn junction, will be modified, and thus care has to be taken to preserve as much as possible of the focusing effect of the envelope to maximise the total irradiance. Because the envelope of existing LEDs have a tapered shape to assist their removal from the mould during manufacture, the shaped side faces can be formed around the broader base of the LED to change its cross-section, for example to become hexagonal, but with these faces having a reducing effect on the shape of the envelope towards its tip where the focusing effect of the envelope is concentrated. Thus the invention can employ existing LEDs and modify their shape in a secondary manufacturing process, for example, using jigs, or the invention can employ LEDs which have been specially manufactured with the required outer shape to accommodate better clustering.

The device according to the invention also preferably incorporates tapered light guides to collect light emitted by the LEDs and deliver this as an output beam. It is known to use light guides with adiabatic optical tapers in optical irradiation devices so that there is total internal reflection of the light as it is conducted from the light source to the output. However, an advantage of the invention is that the more compact cross-section of the LED cluster means that the diameter at the input end of the light guide can be smaller, and thus a smaller angle of adiabatic taper (i.e. the ratio of the diameter of the input end to the output end of the light guide) can be provided in the light guide with the consequent more efficient transmission of radiant energy and increased illuminance. This improvement is most marked compared with a conventional approach of simply increasing the numbers of LEDs in a cluster at ever increasing diameters with decreasing

beneficial effect on illuminance and increasing detrimental effect on compactness, heat generation and cost.

In a preferred embodiment of the invention, a single tapered light guide 41 is provided, as shown in Figure 4. If required the light guide can be curved along its length to direct the output beam to suit a particular application, this being a known practice with existing light guides. The light guide may be machined from cast acrylic plastic and bent, or could be made from glass or other optically transparent materials.

It will be appreciated that the irradiance of a device according to the invention can be varied by varying the input power, number of the LEDs, or by varying the adiabatic taper of the light guide.

In alternative embodiments of the invention, instead of providing a single tapered light guide, each LED or groups of LEDs could be provided with its own light guide fibre incorporating an adiabatic optical taper and the output ends of these fibres can be collected together to form a single output beam. The input end of the fibre would be moulded optically to the adjacent LED or group of LEDs for efficient transmission of radiation. In yet another embodiment of the invention, each LED could be adjusted so that its outer envelope is extended into a fibre light guide which incorporates an adiabatic optical taper.

Cooling of the LED cluster is aided by arranging that the electrical connections 44 of each LED 43 are connected to heat sinks as shown in Figure 4, which are thermally

connected via heat conducting elements to a metal outer case of the cluster. The hotter of the leads is preferably placed nearer the outer case of the cluster so that the heat path of the hotter lead is shorter. If required additional forced cooling means may be used, for example a fan or peltier device.

The wavelengths of the LED used will depend upon the applications of the device. A LED emitting blue light with a peak wavelength of about 470mm is used to harden dental polymers, but a LED emitting red light may be useful for photodynamic therapy, for example, cancer therapy.

The choice of LED is also important in terms of its diameter, irradiance and light angular spread pattern. The optical geometry of the LED has an important effect and from a range of known blue light LEDs the best available choice has been determined as that with 3mm diameter rather than 5mm diameter, an angular spread of 30 degrees rather than 15 or 45 degrees, and an intensity of 500 millicandelas, mcd, rather than the much higher intensity of 2000 millicandelas, mcd, or much lower intensity of 350 millicandelas, mcd, available with some blue light LEDs. Nichia is the manufacturer of these LEDs.

The power supply for the LEDs of the device according to the invention could be mains power, battery power or solar power.

CLAIMS

1. An optical irradiation device comprising a cluster of light emitting diodes, in which opposing faces on adjacent light emitting diodes are shaped to complement one another.

2. An optical irradiation device as claimed in claim 1, wherein the cluster of light emitting diodes is arranged to increase the ratio of occupied to unoccupied space in the cluster.

3. An optical irradiation device as claimed in claim 1 or claim 2, wherein the cluster is arranged radially.

4. An optical irradiation device as claimed in claim 1, claim 2, or claim 3, wherein the cluster includes a first ring of light emitting diodes.

5. An optical irradiation device as claimed in claim 4, wherein the first ring of light emitting diodes is arranged around a central light emitting diode.

6. An optical irradiation device as claimed in claim 5, wherein the cluster includes a second ring of light emitting diodes arranged around the first ring.

7. An optical irradiation device as claimed in any one of the preceding claims, wherein the opposing faces on an adjacent pair of light emitting diodes are flattened.

8. An optical irradiation device as claimed in any one of the preceding claims, wherein opposing faces on an adjacent pair of light emitting diodes are respectively concave and convex.

9. An optical irradiation device as claimed in any one of the preceding claims, wherein the light emitting diodes in an adjacent pair abut along their shaped faces.

10. An optical irradiation device as claimed in any one of the preceding claims, further comprising a light guide for collecting light from the cluster of light emitting diodes.

11. An optical irradiation device as claimed in any one of claims 1 to 9, wherein a light guide is provided for each light emitting diode in the cluster.

12. A light emitting diode adapted for use in an optical irradiation device as claimed in any one of claims 1 to 12.

13. An optical irradiation device substantially as described herein with reference to Figures 1 to 4 of the accompanying drawings.

14. A light emitting diode substantially as described herein with reference to Figures 1,2, and/or 3 of the accompanying drawings.

(FIGURE 4)

ABSTRACT

An optical irradiation device incorporating a cluster of adapted LEDs. The adapted LEDs are arranged so that the density of LEDs in the cluster may be increased compared to existing irradiation devices.

FIG. 4

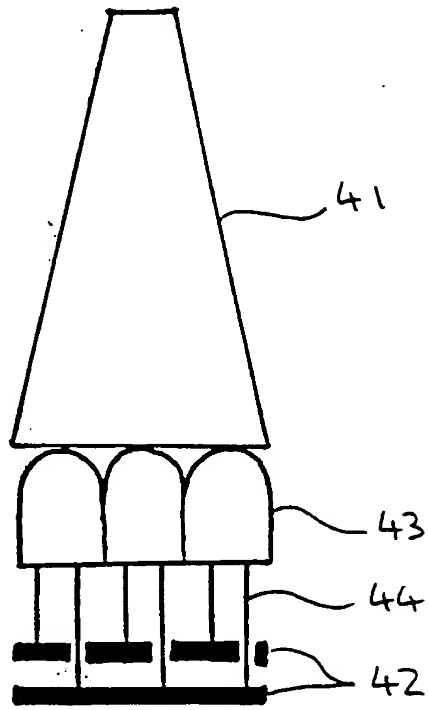

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FIG 1.

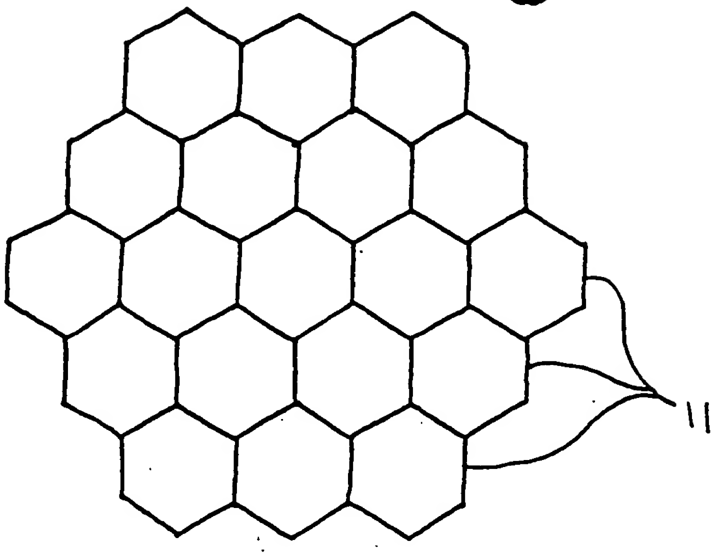

FIG 2.

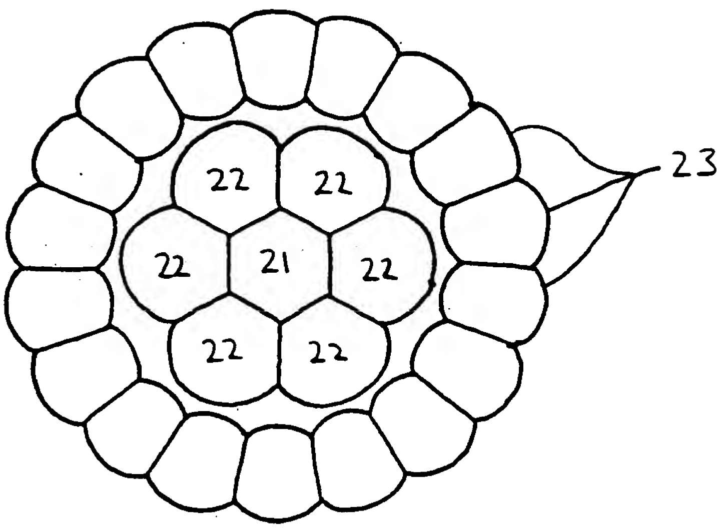

FIG 3.